Report for 2002SC1B: Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina

There are no reported publications resulting from this project.

Report Follows:

Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin in South Carolina

STATEMENT OF CRITICAL REGIONAL OR STATE WATER PROBLEM

As basic natural resources become more scare with increased population and development, various government entities come into conflict with each other over these resources. Clean water and clean air are basic resources any community needs to support life and maintain living standards. Already in the Southeast US, conflicts have arisen between communities over the right to clean water versus the need to develop economically. A prominent national example has been the dispute between Canton, NC on the Pigeon River and towns and citizens downstream from Canton. The question persists, does one community, in its efforts to develop a strong economic base have the privilege of spoiling water or air resources that must also be used by communities downstream or downwind? Answering these questions is more in the realm of law and land use policy. However, as these issues become more heated, there arises a need for clear fundamental research into cause and effect as it relates to clean water and air. In cases such as Canton, NC, a single paper mill can clearly be seen to impair out-flowing water quality. Much different is the circumstance such as the dispute between Greenwood and Greenville, SC. Greenwood takes its drinking water from Lake Greenwood on the Saluda River (Fig. 1). Upstream lies Greenville. The Reedy River, a tributary of the Saluda, flows through downtown Greenville. The upper reaches of the Saluda flow through the greater Greenville metropolitan area. Greenville has a famously protected municipal reservoir and prides itself on the quality of its drinking water. The Greenwood reservoir, on the other hand, shows many of the symptoms one might expect from a "downstream" water resource: sedimentation, nutrification, and algae blooms. Therein lies the debate. Water flowing into Greenville reservoir is clean. Water flowing into Lake Greenwood is much less so.

Professionals working in resource management, water quality, land use and such may feel there is abundant research tying land use/land cover to water quality downstream. Certainly much research has been aimed at this issue. What becomes apparent in listening to disputes between communities is the extent in which fundamental research does not translate to sound policy or even to informed debate. One community can assert, using "conventional wisdom", often supported somewhat by research, that agricultural land use is a severe stress on water quality. As such, it is the quantity of agricultural land on within the Saluda Watershed that may cause the impairment. This point of view gains support following well-publicized stream contaminations at swine farm sites in NC in the mid 1990s. The other community, citing other "common knowledge" claims that urban/suburban/industrial land use is the most damaging. Again, research may even be cited in support of this. What is missing is information tying the specifics of reservoir impairment to specific land use in the watershed above the impairment. In other words, in this particular case, what appears to account for the bulk of the impairment to the inflow of Lake Greenwood. Without this level of information, debates between communities regarding water quality cannot rise above accusation and finger pointing.

Priority Ranked Watersheds in the Saluda River Basin

For DO, FC, P And pH Impairments

Watershed Classification

- Ranked for One Cause
- Ranked for Two Causes
- Ranked for Three Causes
- Ranked for Four Causes

SCALE 1 : 2,350,000

20   0   20   40   Miles

Greenville

Saluda

Reedy R.

Saluda R.

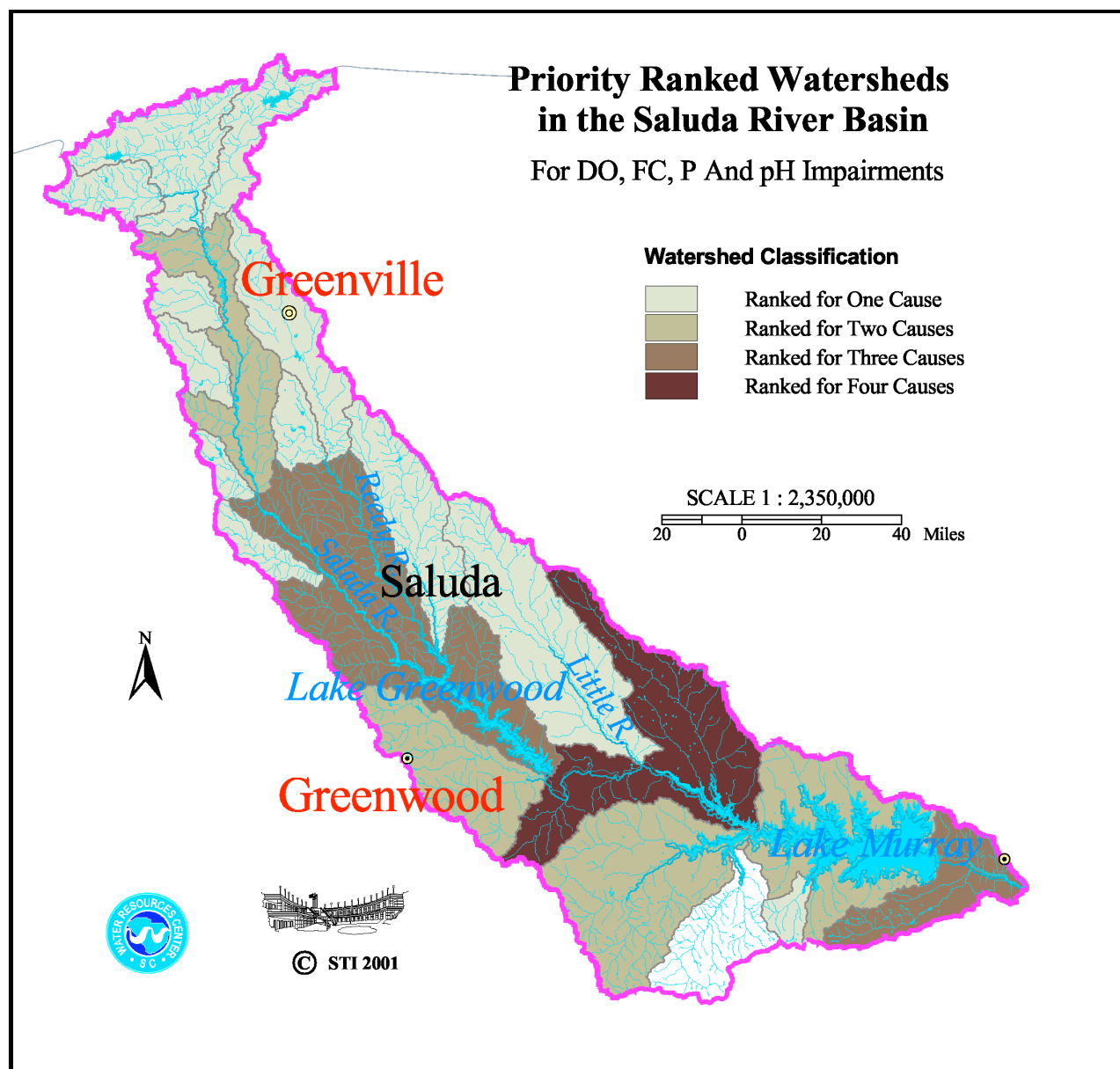Lake Greenwood

Little R.

Greenwood

Lake Murray

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Figure 1. Saluda Watersheds and Priority Ranked Subwatersheds

STATEMENT OF RESULTS OR BENEFITS

For policy makers to make sound decisions on water quality they need sound information. Their information must be correct but also appropriate to the scale that they operate. Highly detailed studies showing the transport of sediment and nutrients across different land covers do not help a planner assess which of two possible sources of water impairment is most critical. Region wide studies showing trends in water quality also do not indicate whether those trends hold for a single watershed of interest.

The proposed research seeks to provide a level of information targeted to the subject at hand. What is the status of current land cover/land use and how much have they changed? Are there any water quality problems, where are they located, and how serious are they? Do land cover and land cover change account for any watershed impairments? What has been the major cause or contributor to the problems? In this way, we hope to provide a better level of information to the public debate on water quality. The issues are real and important to the communities involved, and only when research data is provided to policy makers in an understandable form can it be used in the public forum to guide land use policy.

NATURE, SCOPE AND OBJECTIVES OF THE RESEARCH

The proposed research effort seeks to provide alternative techniques for assessing water quality and its relationship with land cover/land use using remotely sensed data and geographic information systems based on a spatial approach. The goal of the project is to provide better information for public agencies and private organizations to make wise decisions in watershed planning, management prioritization, and plan implementation.

This effort will be confined to the Saluda River Watershed (Fig. 1), which includes Lake Greenwood and the Reedy River tributary. The cities within the watershed are Greenville, Greenwood, Laurens, Simpsonville, and Easley, SC. There are 19 USGS, 11-digit hydrologic units within the Saluda River watershed. These rivers have shaped and been impacted by rapid urbanization and industrialization especially over the last two decades. A recent study (Allen & Lu, 2001) has shown that all but one of these sub watersheds has encountered fecal coliform impairment problems that have been prioritized for management action in the 2000 303(d) list. As South Carolina continues its rapid urbanization, pressure on water resources and watershed environments are anticipated to increase in this watershed area.

Specifically, the objectives of this research project are to:
(1) Extract land cover and change information for the Reedy River and Saluda River Basin using remotely sensed data.
(2) Identify water bodies (stream segments, lake areas) and subwatersheds impaired by fecal coliform and excessive nutrients.
(3) Determine spatial relationships between water quality and land cover using geostatistical methods and BASINS model.

PROJECT METHODOLOGY

This research relies mainly on remote sensing technology and geographic information systems for data sources, change detection, watershed mapping, spatial analysis and modeling. Land cover and change information will be extracted from LANDSAT Thematic Mapper (TM) multispectral imagery and SpectraTech's hyperspectral imagery. Watershed impairments will be measured in terms of fecal coliform and excessive nutrient problems and multiple sources of data will be integrated into GIS for mapping and analysis. The spatial relationship between water quality and land cover will be examined using geostatistical methods and existing data will be used to calibrate EPA's BASINS model. This model will be used to quantitatively determine the possible impact of observed land cover change on water quality in the study area. This effort intends to be less a data

collection process and more of a data gathering, processing, interpreting, analysis task. All the imagery processing and analyses will be conducted using ERDAS imagine and ENVI software package. Spatial analysis and mapping will use ArcView (3.3a). Statistical analyses will be performed using SPSS.

Extracting Land Cover Information
Timely, accurate information of land cover and change is essential to the assessment of the impact of land use change on watersheds. Currently, there has been no such type of data available in the upper state region. The most recent land cover data was collected in 1989 by the South Carolina DNR and not appropriate for this research. Although the agency has started a statewide land use/ land cover change detection project on a county-by-county basis, counties in the upper state region have not been scheduled on the priority list. Therefore, it is necessary to create new land cover and change data sets for this project.

Three remotely sensed data sets will be used to extract and validate land cover and change for the study area. LANDSAT Thematic Mapper (TM) and NAPP aerial photography will be acquired for 1995, 1998, and 2001. TM satellite images (seven spectral bands and 30 x 30m spatial resolution) will be utilized for land cover classification. High resolution of NAPP orthophotos will be used for ground truthing using a random sample of points. Only three principal classes (water, urban, and nonurban) of land cover will be used for this project. While other projects have used highly detailed land cover classifications to correlate with water quality, this project seeks to determine if a simpler, low cost classification might be sufficient for our needs. A post-classification change detection will be performed rather than image (spectral) differencing for generating land cover change. A third set of data is SpectraTech's hyperspectral imagery, which has 37 spectral bands with spatial resolution of 2-3 meters. Since hyperspectral data has great potential to precisely classify materials of interest, it will be used to detect stream or water contaminants. It may also complement NAPP orthophotos in assessing the accuracy of the TM classification.

It is relatively costly to purchase and process these image data. Fortunately, most imagery data sets, especially TM and NAPP orthophotos, will be available for this research by way of data sharing with another project. This related project is tasked to detect urban forest change in the I-85 Corridor in the Upper State South Carolina. This project has a significant overlap with the Saluda Watershed. There will be only 2 scenes of TM images purchased to supplement the land cover classified from this I85 Corridor study. The algorithms of land cover classification and change detection used for the current project will conform to the protocol used in the I85 Corridor project. The simplified, 3-classed land cover is being used nationwide in urban forest change assessments. The 3 classes are much easier to derive than a typical Anderson Level II classification would be. By using this type of classification, we will be able to reduce our cost by using the existing classifications provided by the I85 Corridor Study. This avoids the duplication of effort and save a lot of money and manpower.

Assess Watershed Impairment
Impaired water bodies must be identified before being mapped out for public use and decision-making purpose. This research attempts to identify, map and assess the water bodies with problems of fecal coliform and excessive nutrients that are closely related to urbanization.

There are four data sets that can be used for deriving water quality information. The first set from EPA, embedded in the BASIN model, which has time series data that can be used for model calibration. The water quality indicators are continuous field values and may be more appropriate for analysis that emphasizes within-region differentiation, but the number of sampling sites is often too small for local level analysis. The second set of data are those from the 2000 303(d) list prepared by the South Carolina Department of Health and Environmental Concern (DHEC). They are more recent and have been reduced to four discrete classes, three for priority ranked water bodies and one for the unranked one. They can be treated as normalized data and the ranked water bodies are where the problems are. The third set of water quality data are being collected continually for a research effort conducted by Dr. Deanhardt, funded by a private foundation. Several techniques were used to record levels of nitrate and phosphorous in lake water. These parameters are common indices of nutrient load. The last data set, as ground truth for the hyperspectral imagery, was collected simultaneously with the airborne hyperspectral data. Thirty-five samples were taken from the Reedy and Saluda Rivers. Sampling sites were selected in an interval of approximate 5 miles with consideration given to easy access. Locations of sample sites were recorded using GPS and differentially corrected. Samples were sent to Lander University for lab work that includes fecal coliform (FC), dissolved organic carbon and water chemistry analysis. However, all these data are incomplete and inconsistent in terms of spatial coverage, items collected, and time collected.

It is the intention of the researchers to explore the possibility of using the hyperspectral imagery to identify impaired water bodies or pollutants. Hyperspectral technology was originally developed to aid in mining and petroleum exploration (Lunetta and Elvidge 1998) by detecting stressed vegetation as indicators of subsurface items of interest. Hyperspectral data continues to be used to precisely classify and differentiate vegetation (Price 2001, Gamba and Houshmand 2001, Hepner 1998), but has not been tested extensively for water pollution identification and monitoring in South Carolina or elsewhere. It is acknowledged that many pollutants cannot be reliably identified from imagery. It is more likely that sediments, turbidity, fecal coliform or alga booms, are discernable from the hyperspectral imagery. Success of this effort will have significant implication both in the fields of remote sensing and water quality monitoring.

Correlate Water Quality and Land Cover
This research takes a spatial and watershed approach to determine the relationship between water quality and land Cover. Two different methods will be used to delineate watershed boundaries, and therefore, the units of analysis and modeling. One method is the sample site or pour point delineation based on building watersheds above the sample sites using USGS 30-meter Digital Elevation Models and GIS software. In this case, each sample data point will have an associated contributing watershed. The other method is to use watershed boundaries defined by USGS. The 11-digit hydraulic units are preferred to keep the spatial precision as small as possible. However, some water quality data must be reaggregated to adjust between the watershed types, which may lead error. In either case, land use and land cover data must be aggregated for each watershed in order to conduct geostatistical analysis. US Census data of 1990 and 2000 will also be integrated into GIS database and population and housing data at the block level, the smallest unit, will be reaggregated for each watersheds. Other spatial data representing environmental factors will be used for spatial analysis to reflect the effects of variation of natural variables on the conditions of water quality.

As in a study on animal agriculture and watershed impairment (Allen and Lu 2001), canonical correlation, multiple regression and Pearson correlation will be performed to examine the spatial relationships between water quality indicators and land cover and land use variables. The purpose of these analyses is to determine statistically if there is a close association between watershed impairments and human and natural variables, how strong the relationship is, which variables and factors are significant, and how water quality varies with land cover changes.

Many water and land resource professionals are familiar with EPA's BASINS water quality and quantity model (3, 4, 5). This software is available within ESRI's Arcview GIS package. BASINS uses land use GIS data with many other parameters, including rainfall and topography to predict the quantity and quality of water flowing through a watershed pour point. BASINS can be calibrated using available water quality information. We will use the data from Lake Greenwood for this purpose. The primary purpose of using the BASINS model in parallel with Task 1 is to provide a comparison of our model with a familiar index of water quality and not as a goal of its own. The purpose of this project is to provide specific water quality information for public policy professionals in a form readily understood by the public. Still we recognize the need to relate this analysis to accepted and familiar models in order to gain the trust of land and water resource professionals and provide a context for our model.

RELATED RESEARCH

In the wake of well-publicized water contamination problems in NC involving large-scale swine farms, there was great concern in South Carolina over the prospect of a similar problem in SC. The public was justifiable concerned with water quality and the prevailing public opinion was tilted toward the assumption that animal agriculture was a primary contributor to water pollution. The SC legislature, in the mid to late 1990s, enacted a very restrictive farm bill, essentially curtailing large scale hog farms, partially based on this public opinion, and perhaps without a sound scientific basis. The SC Agricultural Extension sought to determine public sentiment on agriculture and water quality. SC extension conducted surveys and compiled data that was later published in a book "Animal Agriculture in South Carolina: A Fact Book." The Strom Thurmond Institute contributed to this effort by creating maps of agricultural animal populations and watershed impairment. These maps and associated analyses were found in the article "Spatial Relationships of Polluted Streams, Animal Agriculture, and Human Population in South Carolina Watersheds" in 1998 (Allen et al 1998). USDA Agricultural Census data from 1992 were displayed on top of USGS 8-digit watersheds, coded by SC DHEC 303d assessment of impairment. The 1997 303(d) impairment information indicates whether or not a watershed is impaired on a certain parameter, including dissolved oxygen and fecal coliform. This information is then classed 0 (unranked), 1, 2, or 3 based on the number of impairments. No statistical analysis was attempted on this data. This was simply a mapping of available data. The maps seemed to suggest, though, that animal agriculture was not the only contributor to water quality impairment, at least in SC.

When the maps were published, the level of public, government and farm industry was striking. Many pointed out some weakness in this simplified mapping approach to the issue. 8-digit hydrologic units for watershed impairment is too coarse to truly assess site-specific impacts on

water quality; no statistical analysis has performed to support the conclusion based on the visual interpretations of maps.

There was sufficient interest in this analysis to fund a second phase of the project to address some weaknesses of the first project. In the second phase, updated data were used and the spatial resolution improved. Four types of impairments (DO, FC, P and pH) were mapped out at the USGS 11-digit hydrologic units using South Carolina 2000 303(d) list. In addition to the updated Agricultural census data, the research has incorporated animal facility data that does not only provide rich information about animal related variables but also better for data aggregation with little error propagation. Four statistical methods, which include canonical analysis, multiple regression, Pearson correlation and crossable summary, were used to perform a comprehensive spatio-statistical analysis. It was found that animal agriculture as a whole does provide a week but statistically significant contribution to watershed impairment but it is not the major factor. Animal Agriculture left over 80% of the variance in watershed rank scores unexplained. This suggests that other factors, such as human population, could be the major contributor of watershed impairment problems. Unfortunately, those factors were not taken into consideration in this research.

Although several studies of land cover classifications, change detections, and even urban prediction have been done in South Carolina (Allen and Lu 2000), none of them have taken place in the Saluda watershed. None of them have addressed the impact of land use change on water quality explicitly. EPA's BASINS software has been around for a while and it uses land use/land cover data as its parameters, but no applications has been found in the Saluda watershed. This research, therefore, seeks to fill the gap of previous studies, to link land cover and watershed impairments, and to meet regional and local information needs for wise planning and management of precious water resources